Final TECHNICAL REPORT

AN EXPERIMENTAL STUDY OF ATMOSPHERE-IONOSPHERE COUPLING USING MAGNETOMETERS

Submitted by

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Sponsored by
Advanced Research Projects Agency (DOD)
ARPA Order 4513
Program Code 2A10
Monitored by AFOSR/NP under Grant ~~AFOSR~~ AFOSR-82-0193

The Regents of the University of California
University of California
405 Hilgard Avenue
Los Angeles, CA 90024

2/15/82 - 11/15/82

$20,000

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER AFOSR-TR- 83-0571	2. GOVT ACCESSION NO. AD-A130057	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN EXPERIMENTAL STUDY OF ATMOSPHERE-IONOSPHERE COUPLING USING MAGNETOMETERS		5. TYPE OF REPORT & PERIOD COVERED FINAL 15 Feb 82 - 15 Nov 82
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Janet G. Luhmann, Paul J. Coleman, Jr.		8. CONTRACT OR GRANT NUMBER(s) AFOSR-82-0193
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of California 405 Hilgard Avenue Los Angeles, CA 90024		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2309/A1 61102F
11. CONTROLLING OFFICE NAME AND ADDRESS AFOSR/NP Building 410 Bolling AFB, DC 20332		12. REPORT DATE Nov 1982
		13. NUMBER OF PAGES 10
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Based on magnetometer observations in the vicinity of three underground tests at the Nevada Test-Site during 1982, it is concluded that perturbation currents produced in the ionosphere by the atmospheric disturbance launched by the ground movement are too weak relative to the natural ULF background to be detected easily with ground-based magnetometers at remote sites. In spite of this negative conclusion, the possibility exists that sophisticated data processing techniques could be applied to the records from two stations to extract a weak signal of uncertain form from these records. We know from the Mt. St. Heles event that these

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20. effects can be measurable. We do not know how the effect scales to perturbations of the type caused by the underground tests. It is strongly recommended that some theoretical predictions of the expected size of the perturbation currents for various atmospheric disturbances be carried out in advance of future experiments.

SUMMARY

On three occasions, portable magnetometer experiments with automated data systems designed especially for unsupervised operation were sited within a 50 km radius of underground nuclear tests at the Nevada Test Site. The purpose of these experiments was to determine whether the disturbance of the atmosphere by the ground movement related to the test created a measurable perturbation current in the ionosphere. Preliminary analyses of the results suggest that the natural ULF magnetic background is too noisy to allow the certain identification of a test-related signal by visual inspection of chart records. However, more sophisticated computerized methods can be applied to identify small differences in magnetic fields measured at several sites. The negative result reported here is thus qualified to the extent that we have not made use of these more sensitive data analysis tools.

I. DESCRIPTION OF THE EXPERIMENT

Sudden disturbances of the neutral atmosphere by above-ground nuclear tests, explosions, volcanic eruptions and earthquakes have been observed to produce traveling atmospheric waves with periods ~10-30 minutes at ionospheric altitudes (~80-300 km). In the case of Mt. St. Helens, the waves collisionally coupled to the ionosphere, resulting in oscillating perturbation currents that were observed across the U.S. with the Air Force magnetometer network that was designed and constructed by our group at UCLA (Fougere and Tsacoyeanes, 1980). Because the ground movement caused by nuclear tests produces local atmospheric effects that are detectable by ionosondes, the Nevada Test Site provided an opportunity to investigate this particular manifestation of atmosphere-ionosphere coupling in a relatively controlled experiment. Magnetometers (2-3 separate instrument packages with specially designed automated data systems) were deployed by UCLA at sites within 50 km to 150 km of the ground zero during three tests in 1982. The locations of two of the magnetometers are identified in Figure 1, which shows Frenchman and Area 25, while the third site at Pahrump is approximately 60 km south of Area 25. Most of the tests occurred in the vicinity of Pahute Mesa.

The atmospheric waves that are observed to travel great horizontal distances in the ionosphere have the property that they are practically noncompressive, i.e. they appear as corrugations of isodensity surfaces of the neutral atmosphere. They have wavelengths of ~20-2000 km, periods of 10 minutes to several hours, and horizontal phase fronts that travel at speeds ~300 m s^{-1} (cf. Hines, 1974). Collisions between neutral particles, which are performing oscillatory motions in these waves, and the ions and electrons in the ionosphere produce oscillating currents because the ions and electrons have different cross sections for collisions with the neutrals. Magnetometers on the ground detect magnetic fields from every element of the ionospheric current-carrying volume illustrated schematically in Figure 2. However, the magnetometers also detect currents that are associated with natural ULF geomagnetic activity.

Natural geomagnetic activity in the period range 5-20 minutes, belonging to the class of Pc 5 micropulsations, occurs regularly (cf. Campbell, 1976). The feature of the Pc 5 micropulsations that distinguishes them from the atmospheric-source "pulsations" is that the Pc 5 pulsations occur simultaneously over a large area of the earth, while the atmospheric wave related disturbance should appear to travel with a ~300 m s^{-1} velocity between magnetometers situated at spaced sites. It was hoped that the natural ULF background during the underground tests would be at a low enough level to allow the identification of the traveling atmospheric disturbance in at least two of the magnetometer records, thereby permitting verification of the atmospheric origin by virtue of the time delay.

For magnetometer sites at 40 km and 110 km range, for example, the significance between the arrival times of the effects of the current perturbations would be about 3 minutes. We sampled the local magnetic field every 10 s, in order to be able to resolve such a separation. A sensitivity of .1 nT (nanoTesla = 10^{-5} Gauss) was deemed adequate for any practically usable signal. The natural background was also monitored throughout the 24 hours prior to each test and ~3 hours after each test.

II. RESULTS

The monitored underground tests occurred 24 June, August and 29 September 1982. An example of the magnetic field data from two stations for the 24 June test is shown in Figure 3. The magnetometers measured the local magnetic field along three axes: the z axis was pointed along the local (undisturbed) field direction, the x axis was perpendicular in the plane through the north pole, and the y axis toward the east. All data displayed in Figure 3 have been filtered with a high pass filter in the laboratory in order to eliminate fluctuations in the measured field with periods greater than the maximum expected signal period of ~1 hour. It should be noted here that some differences in the behavior of the records at different sites are related to the unique pattern of the local ground conductivity. However, we are interested in features with ~10 minute periods or longer that have apparent time delays of ~3 minutes between stations and occur within minutes of the test.

The test time is marked with arrows in Figure 3. Although the data show many oscillations of ~10 minute period, they occur both before and after the test and at equal phases. There is no reason, based on visual examination, to attribute these oscillations to anything other than natural Pc 5 activity. The other test results show similar characteristics. A similar examination of natural activity in the data from the nationwide Geophysics Laboratory magnetometer chain supports this conclusion.

III. CONCLUSIONS

Based on magnetometer observations in the vicinity of three underground tests at the Nevada Test Site during 1982, it is concluded that perturbation currents produced in the ionosphere by the atmospheric disturbance launched by the ground movement are too weak relative to the natural ULF background to be detected easily with ground-based magnetometers at remote sites. In spite of this negative conclusion, the possibility exists that sophisticated data processing techniques cold be applied to the records from two stations to extract a weak signal of uncertain form from these records. We know from the Mt. St. Helens event that these effects can be measurable. We do not know how the effect scales to perturbations of the type caused by the underground tests. It is strongly recommended that some theoretical predictions of the expected size of the perturbation currents for various atmospheric disturbances be carried out in advance of future experiments.

ACKNOWLEDGEMENTS

The experiments were carried out through the dedicated efforts of R. C. Snare and F. R. George, and with the help of J. D. Means, D. Dearborn, D. Pierce, and D. Sentman.

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Fougere, P. F., and C. W. Tsacoyeanes, EOS (Trans. Am. Geophys. Union), 61,]1209, 1980.

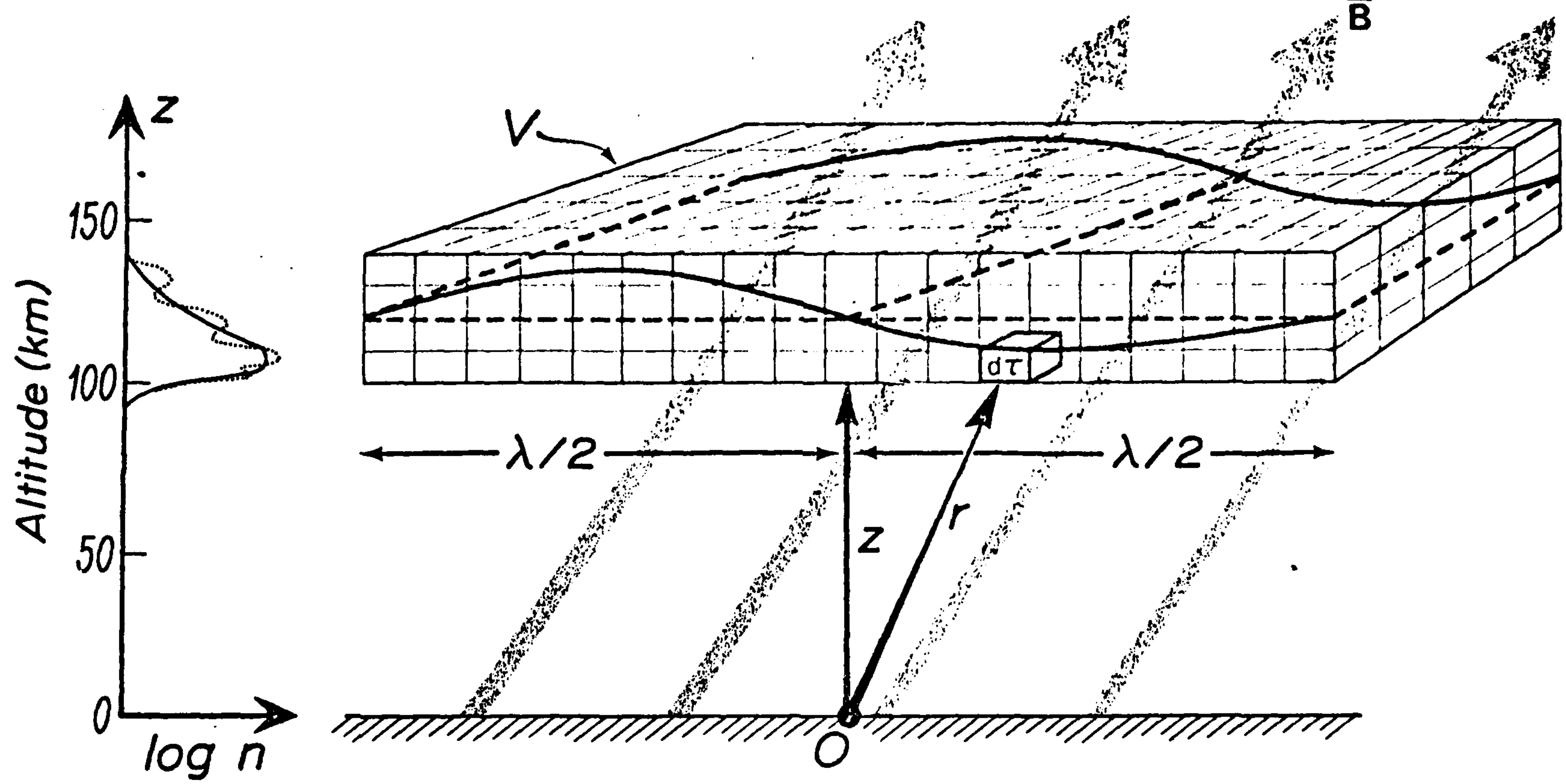
Hines, C. O., The Upper Atmosphere in Motion, American Geophysical Union, Washington, D.C., 1974.

Figure Captions

Figure 1: Nevada Test Site, showing locations of magnetometers during the experiments ([]). Pahrump, the third site, is off of this map, about 60 km south of Area 25. The tests occurred near Pahute Mesa.

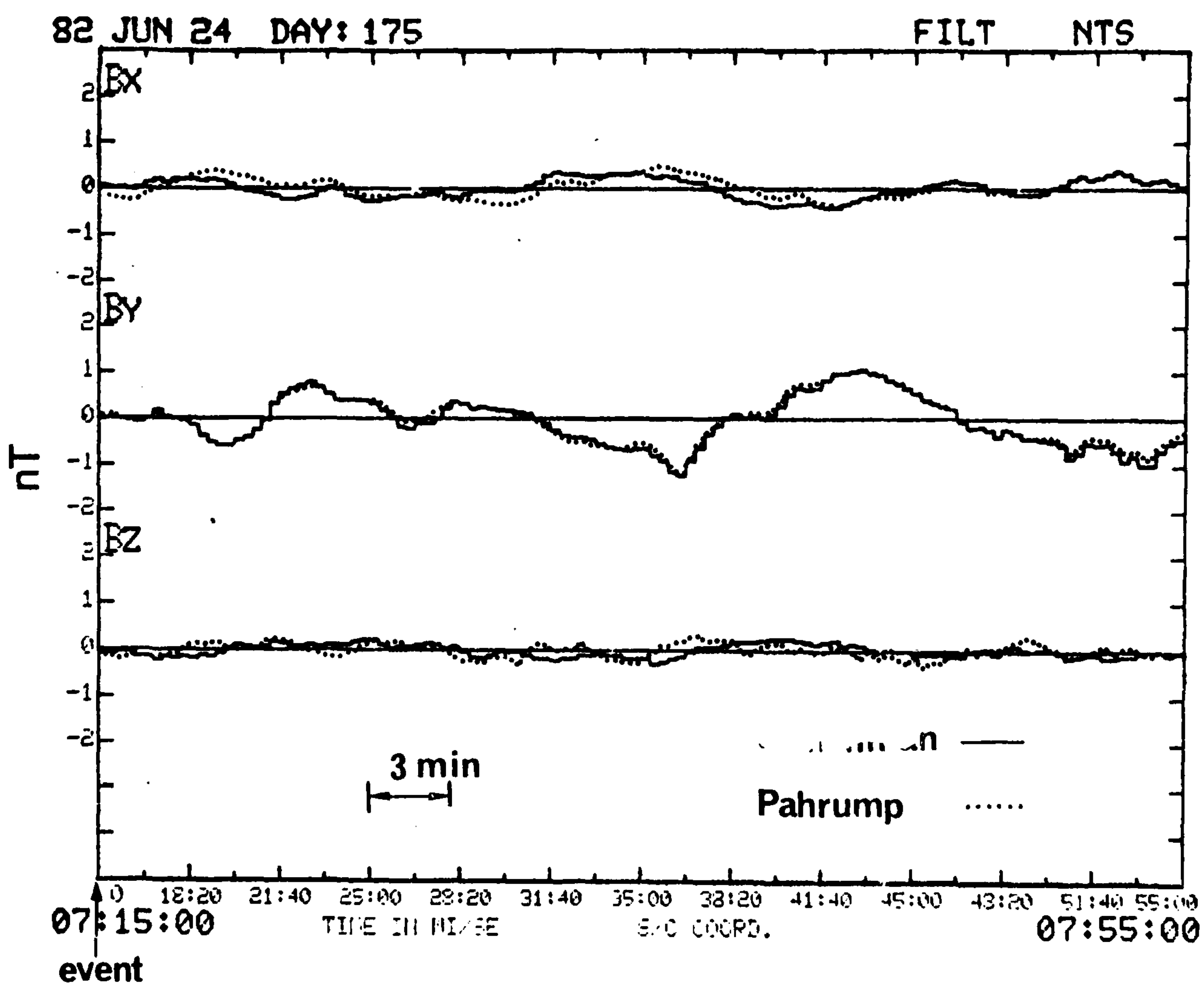
Figure 2: Schematic illustration of an atmospheric wave of wavelength λ passing through the ionosphere volume V. The perturbed and unperturbed altitude profiles of ionospheric electron density are shown on the left, while the background geomagnetic field direction $\overline{B}$ is indicated by the shaded arrows. The magnetometer located at 0, which normally measures the internal field and the fields from natural current perturbations above and within the ionosphere, is affected by the additional oscillating currents caused by the passing atmospheric wave. At the bottom of the diagram, the Bio-Savart integral expresses the point that the measured field perturbation $\delta\overline{B}$ includes the field produced by currents in each volume element d overhead.

Figure 3: Example of magnetometer data for two different time scales (see text for description). Pahrump observations are the top three traces; Frenchman data are the bottom three. The time of the test is marked by arrows.



$$\delta\bar{B} = \frac{\mu_0}{4\pi} \int_V \frac{\bar{J} \times \bar{r}}{|r|^3}\, d\tau$$

Figure 2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1
0
-1
-2
3 min
Pahrump
0
18:20
21:40
25:00
28:20
31:40
35:00
38:20
41:40
45:00
48:20
51:40
55:00
07:15:00
07:55:00
event

Figure 3

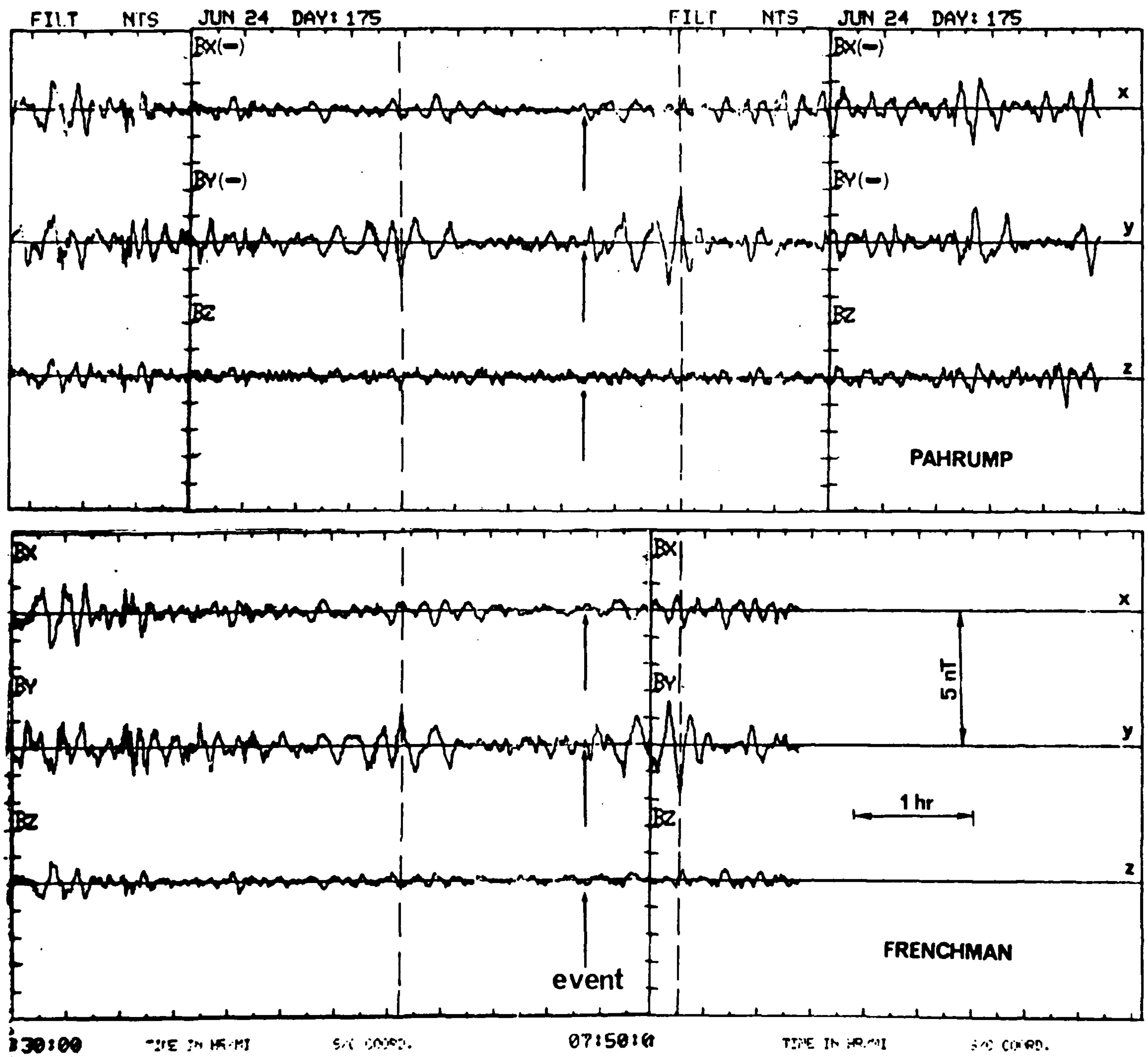

Figure 3
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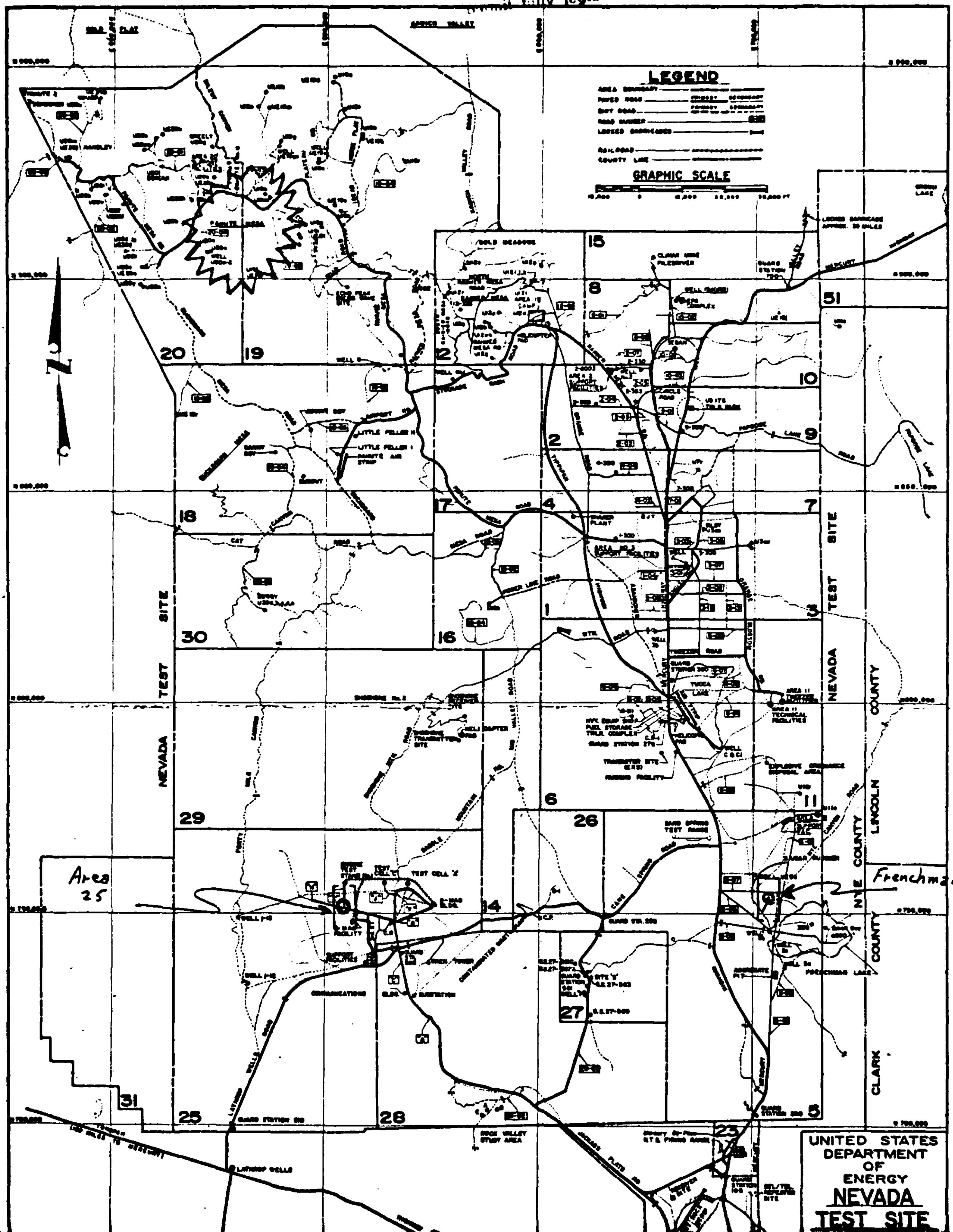
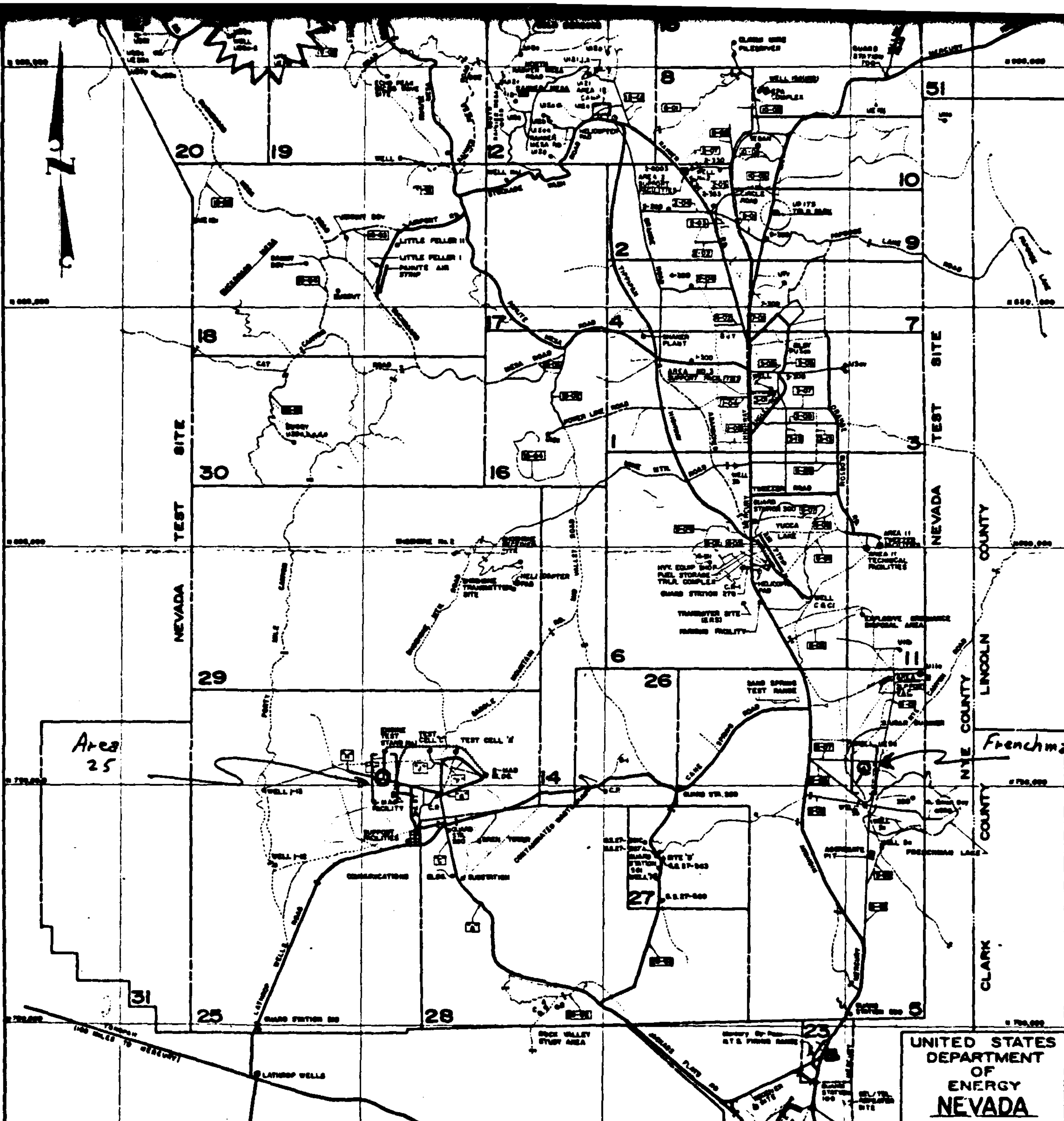

LEGEND
GRAPHIC SCALE
15
8
51
20
19
12
10
2
9
17
4
7
18
1
3
30
16
NEVADA TEST SITE
NEVADA TEST SITE
NYE COUNTY
LINCOLN COUNTY
NYE COUNTY
CLARK COUNTY
29
6
26
11
Area 25
Frenchman
14
27
31
25
28
5
23
PAIUTE MESA
LITTLE FELLER II
LITTLE FELLER I
TEST CELL 'A'
COMMUNICATIONS
LATHROP WELLS
UNITED STATES DEPARTMENT OF ENERGY
NEVADA TEST SITE


UNITED STATES DEPARTMENT OF ENERGY
NEVADA TEST SITE
ROAD & FACILITY MAP
NEVADA TEST SITE
NYE COUNTY
LINCOLN COUNTY
CLARK COUNTY
Area 25
Frenchman
1
2
3
4
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51
LITTLE FELLER II
LITTLE FELLER I
TEST CELL 'A'
FRENCHMAN LAKE
LATHROP WELLS
GUARD STATION 300
COMMUNICATIONS
SUBSTATION
ROCK VALLEY STUDY AREA
AREA 11 TECHNICAL FACILITIES

Figure 1

2